FRETTING : A LIMITATION FOR DEVELOPMENT OF NEW MATERIALS

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The knowledge of wear maps (the running condition and the response of the materials) allows us to analyse and to understand the tribological behavior of the materials and thus furnishes the bases of a qualification of new materials or of superficial treatments.

INTRODUCTION

Designers now have to choose between a lot of traditional or new materials. The numerous characterizations of advanced materials can give a basis for a rational choice for applications such as fatigue or creep. Once the new materials have been shown to have adequate properties for specific applications, an uncertainty however remains as to wether contact problems can arise. Several problems have to be noted for tribological behavior :

- friction and wear are not intrinsic properties of materials.
- Wear and durability are not identical : wear is material loss and durability relates to a function expressed in terms of duty or life.
- Extrapolation from laboratory benches to industrial applications is hazardous.
- A contact problem must be considered from the so-called triplet which considers mechanisms such as gears, cables, ...,

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first bodies or running materials and the third body which generally separates the first bodies as well under dry or lubricated contacts.

This paper will furnish ways of analysing the tribological behavior of new materials to favor their use and describe their limits for specific applications.

I. GENERAL BACKGROUND

The global behavior of contact surfaces which undergo deterioration can be decomposed into 2 stages :

1) the beginning stage of the degradation.
2) the stage during which this initial degradation of the material influences the contact and modifies among other things, the limit conditions of the contact.

According to the type of degradation, the response of the material can be either the formation of cracks and their propagation (volume damage) or the appearance of debris leading to formation of a third body following the possibilities of trapping which govern it.

The analysis of the local conditions and of the response of the material starting from fretting tests leads to the proposition of wear maps which furnish the bases of a potential ranking of the behavior of materials.

The results presented here depend on a tribometer for small displacements described on numerous occasions (1) (2). The test consists of pinning two samples under a normal effort, imposing a D displacement using an extensometer and measuring the tangential effort F.

In relation to the conditions recorded during contact (normal load, imposed displacement real displacement) (1) several types of effort tangential-displacement can be obtained (figure 1) :

- a closed cycle (Figure 1.a) corresponding to a sticking of the surfaces in contact and to an elastic accommodation of the displacement by first bodies and by the test set-up.
- a quasi parallelogram cycle (Figure 1-b) corresponding to a total sliding. The real displacement is less than the imposed displacement. It is generally representative of the formation of debris.
- an elliptic cycle (Figure 1-c) for which the non-linear part corresponds to a reduction in the global rigidity of the system. It is associated in general with a cracking phenomenon.

During the test the nature of the cycle can evolve ; this is sometimes associated with a modification of the tangential effort. Figure 2 presents an example of friction logs which give the evolution of these cycles on a logarithmic scale in the case of cracking (3).

Metallographic observations on the surface and on cross-sections show three response types of the material :

- absence of damage at the observation scale (metallographic section),
- cracking,
- particle detachment.

In certain cases the last two modes can be observed simultaneously. Starting there, it is possible to propose two types of wear maps in a L, D, diagram. One (Figure 3) called a running condition fretting map obtained after several thousand cycles and which thus depends on initial conditions, describes the real conditions in the contact (sticking, partial sliding, total sliding) (4). The other, shows the response of the material (Material Response Fretting Map): it situates the areas of cracking and debris formation and its plotting depends on the number of cycles. For a given set of materials, the knowledge of these maps allows for the definition of the tribological behavior of the materials, the display in particular in the cracking area of the susceptibility of a material in relation to this type of behavior.

II. ANALYSIS OF THE RESPONSE OF MATERIALS

For any attempt to predict the beginning of a fissure, it is essential to know the value of tensile skin stress sxx. Contact mechanics allows for the calculation or, in any case, the approximation of it. It can be compared to the endurance limit of the considered material by associating specific factors such as internal stresses. From this point of view an analogy can be made with the Wöhler curves used in conventional fatigue problems. The fissures are observed between the stuck zone-central zone and the sliding zone in the case of partial sliding - that is at the spot where the sxx is maximal.

In the case of total sliding, the main response is particle detachment. Starting from tests performed on a large range of alloys (iron, aluminium, titanium based,) it has been established that debris form on a new structure which is distinguished by :

- the appearance, whatever the initial phase, of the most stable cristallographic phase of the material. Studies in X rays grazing incidence showed that this transformation appears with the first cycles.

- great hardness associated with a non-oriented nanocrystalline structure rich in defects such as dislocations.

The amplitude of this zone where the debris regenerate is more or less sizeable according to the initial stability of the existing phase. The form of the debris is correlated to the intrinsic properties of the phases revealing a mechanical recristallization. The implementation of the surface treatment, surface alloy or covering will modify the running conditions and the response of the materials. If the thicknesses treated are very thin (several micrometers) there will be an essential modification of the surface properties without the volume effects being modified. If the thicknesses treated are greater (several hundred of micrometers) there will be noticeable modifications of the effort spread from volume and adaptation effects of surface properties to the characteristics of the treated area.

The proposed wear maps allow us to qualify the interest of a particular surface treatment. It is thus possible to display different types of response :

- a treatment can not modify the local running condition map but plays on the response of the material and thus its degradation in contact (reinforcing of resistance to fatigue, modification of the recristallization rate. This is the case, for example, of a carburizing or a nitriding.

- a treatment can modify the local running condition map and consequently the response map which largely depends on the properties of the material under consideration. This can be seen in particular when the surface composition is deeply modified (surface alloying, cladding) and when parameters such as thickness treated, deposit adherence, mechanical characteristics, are going to play a key role.

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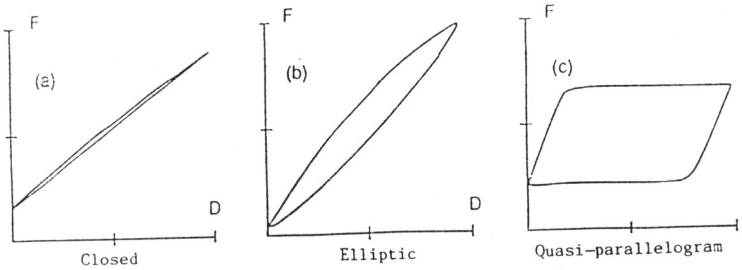

Figure 1 : FD Cycles.

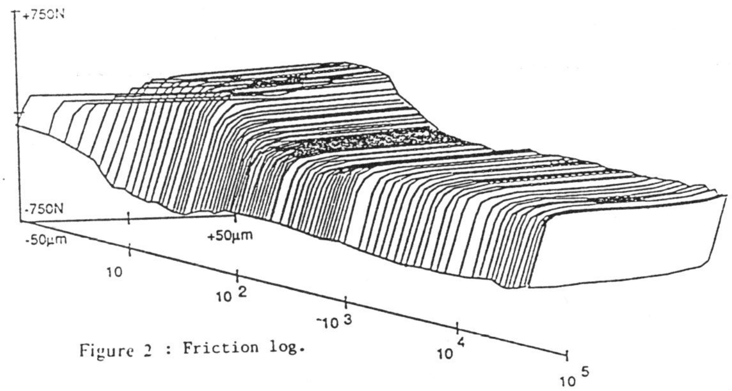

Figure 2 : Friction log.

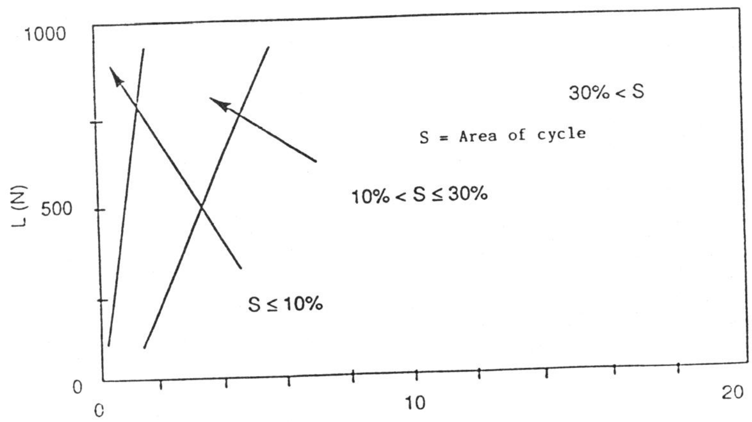

Figure 3 : Running condition fretting map.